KYANITE AND RELATED MATERIALS

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Kyanite, andalusite, and sillimanite are anhydrous aluminosilicate minerals with the same chemical formula (Al_2SiO_5) but different crystal structures and physical properties. When calcined at high temperatures (in the 1,400° C to 1,500° C range for kyanite and andalusite and 1,550° C to 1,625° C for sillimanite), these minerals are converted to mullite ($Al_6Si_2O_{13}$) and silica (SiO_2) (Harben, 1999). During calcination, 1 metric ton (t) of aluminosilicate concentrate yields about 0.88 t of mullite. Synthetic mullite is made by heating mixtures of bauxite and kaolin or alumina and silica at about 1,550° C to 2,000° C (Roskill Information Services Ltd. 1990, p. 55). Mullite increases the fired strength, resistance to deformation under load, and thermal resistivity of refractories. Refractories are the largest end use of kyanite, andalusite, and synthetic mullite in the United States and worldwide.

Company data are proprietary; however, Dickson (2002) has estimated U.S. kyanite output to be about 90,000 metric tons per year (t/yr), which would make the United States the world's largest producer of this mineral (table 3). South Africa continued to be the leading producing country of andalusite, with an estimated 195,000 t in 2002. France produced an estimated 65,000 t of andalusite. There has been limited production of sillimanite. India supplied most of the world's output with an estimated 12,000 t/yr to 14,000 t/yr in recent years. There was no known U.S. output of sillimanite.

Legislation and Government Programs

The U.S. Government stockpile contained a total of 136 t of kyanite at yearend 2002 (Defense National Stockpile Center, 2001§[1]). This quantity has remained unchanged for several years.

Production

Kyanite Mining Corp. operated two open pit mines in Buckingham County, VA, and beneficiated the ore into a marketable kyanite concentrate. The company had two calcining kilns at its Dillwyn, VA, facility for production of calcined kyanite (mullite); further processing and warehousing were also carried out at this site. Reported U.S. production data collected by the U.S. Geological Survey are withheld to avoid revealing company proprietary information. Based on Dickson's (2002) estimated U.S. kyanite production of about 90,000 t/yr, the estimated value of kyanite concentrate was calculated to be about $13 million (before conversion to mullite), using a value of $149 per metric ton. High-temperature sintered synthetic mullite, made from calcined bauxitic kaolin and sold under the trade name Mulcoa 70, was produced by C-E Minerals, Inc. near Americus, GA. Estimated U.S. production of synthetic mullite was about 40,000 t/yr (Dickson, 2002); the corresponding estimated value was about $9.7 million, based on a value of $243 per ton.

Piedmont Minerals Co., Inc. in Hillsborough, NC, mined a deposit containing andalusite combined with pyrophyllite and sericite. The company sells products containing blends of the three minerals to refractories and ceramics producers.

Consumption

Andalusite expands irreversibly by about only 4% to 6% when calcined and can therefore be used directly in refractories in its raw state. Kyanite increases in volume by 16% to 18% on calcining and can be used in its raw concentrate form in a refractory mixture to counteract the shrinkage on firing of other components, especially clays (Dickson, 2002). In other refractory applications, kyanite concentrate is calcined to mullite before being added to refractory mixes because the process for creating mullite restricts any further dimensional instability (Roskill Information Services Ltd., 1990, p. 56).

Examples of refractories that contain andalusite, kyanite, and/or synthetic mullite include insulating brick, firebrick, kiln furniture, refractory shapes, and monolithic refractories (made of a single piece or as a continuous structure), including castables (refractory concrete), gunning mixes, mortars, plastics, and ramming mixes. The interlocking grain structure of kyanite and mullite gives added mechanical strength to refractories and other nonrefractory ceramic articles. End uses of kyanite and related materials also include brake shoes and pads, electrical porcelain, floor and wall tile, foundry use, precision casting molds, sanitaryware, and other products (Kyanite Mining Corp., 2001§).

Foreign Trade

The United States exported kyanite and synthetic mullite to countries in Europe, Latin America, the Pacific rim, and other areas.

[1]References that include a section mark (§) are found in the Internet References Cited section.

Most of the material imported into the United States in 2002 was from South Africa (about 4,530 t with a United States customs value of $872,000) and was presumed to be andalusite (table 2). There were no known U.S. imports of kyanite or sillimanite in 2002.

World Review

China.—Although official data were not available, the number of kyanite, andalusite, and sillimanite mines was estimated to be 100 or more. Production of these minerals was probably higher than that listed in table 3 because of a lag time in reporting official Government statistics. Development of these minerals for the global market was facing transportation challenges (deposits located far from ports) and technical challenges, such as relatively high iron content in the andalusite (O'Driscoll, 2002). Iron as discrete particles in the form of hematite (Fe_2O_3) in andalusite can cause cracking and parting in refractories (Varley, 1968, p. 27).

Japan.—Refractories consumption decreased in recent years, especially in the steel industry. Between 1991 and 2001, refractory production decreased by 27%. Refractory imports from such countries as China, India, the Republic of Korea, and Thailand increased to 128,000 t in 2000 from about 30,000 t in 1991. The unit price of imported refractories was approximately 45% less than Japanese-made refractories. Advances in refractories technology have resulted in longer refractory service life. However, such benefits to customers have a negative impact on the sales of refractories companies (Semler, 2002).

South Africa.—Andalusite Resources (Pty) Ltd. was planning to build and operate a plant to produce andalusite from a deposit at Maroeleosfontein in Limpopo Province (formerly Northern Province). Output was slated to be 2,500 metric tons per month. Apparently, the andalusite was tested with favorable results for both refractory bricks and monolithics (Industrial Minerals, 2002).

Outlook

The refractories industry, the largest end user of kyanite and andalusite, may continue to face some economic challenges. Higher performance refractory products are lasting longer, resulting in lower consumption of refractory raw materials. Specific consumption of refractories in steelmaking, the largest end use of refractories in general, has decreased in the past two decades to 10 kilograms per ton of steel produced from about 20 to 25 kilograms per ton of steel produced. One European steel producer switched to using alumina spinel rather than andalusite bricks in its steel ladles. However, this was not seen as indicative of a general trend. In South Africa, changes in smelting technology have contributed to a decrease in andalusite consumption (O'Driscoll, 2002).

United States imports of refractories, including those from China, have accounted for a significant proportion of overall consumption value (North American Minerals News, 2002). Positive economic developments include the increased U.S. crude steel production of 2.5% in 2002 compared with that of 2001 and the estimated 6% increase in world crude steel output in 2002 (International Iron and Steel Institute, 2002§).

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GENERAL SOURCES OF INFORMATION

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TABLE 1
PRICE OF KYANITE AND RELATED MATERIALS IN 2002

(Dollars per metric ton)

	Price
Andalusite, free on board, Transvaal, South Africa, 57% to 58% alumina, 2,000-metric-ton bulk	183-214
Kyanite, USA (VA), ex-works, 54% to 60% alumina, 18-ton lots, calcined (mullite)	262-295

Source: Industrial Minerals, no. 423, December 2002, p. 71.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF ANDALUSITE, KYANITE, AND SILLIMANITE[1, 2, 3]

Year	Quantity (metric tons)	Value[4] (thousands)
2001	3,260	$569
2002	4,620	952

[1]Most material is andalusite from South Africa.
[2]Harmonized Tariff System (HTS) code 2508.50.0000.
[3]Data are rounded to no more than three significant digits.
[4]Customs value.

Source: U.S. Census Bureau.

TABLE 3
KYANITE AND RELATED MINERALS: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country and commodity[3]	1998	1999	2000	2001	2002
Australia:					
Kyanite	800	1,000	1,000	1,000	1,000
Sillimanite[4]	100	100	100	100	300
Brazil, kyanite	600	600	600	600	600
China, unspecified	3,050	3,000	3,100	3,150	3,200
France, andalusite	70,000	70,000	65,000	65,000	65,000
India:					
Kyanite	5,169 [5]	5,000	5,000	5,500 [r]	6,000
Sillimanite	11,936 [5]	12,000	12,000	13,000 [r]	14,000
South Africa, aluminosilicate[6]	236,265 [r, 5]	136,949 [r, 5]	182,674 [5]	193,225 [r, 5]	195,000
Spain, andalusite	3,000	2,500	2,500	2,500	2,500
United States:[7]					
Kyanite	90,000	90,000	90,000	90,000	90,000
Mullite, synthetic	39,000	39,000	40,000	40,000	40,000
Zimbabwe, kyanite	3,780 [5]	4,000	10,970 [r, 5]	9,682 [r, 5]	10,000

[r]Revised.
[1]U.S. and estimated data are rounded to no more than three significant digits.
[2]Owing to incomplete reporting, this table has not been totaled. Table includes data available through March 21, 2003.
[3]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not

[4]In addition, about 7,000 metric tons per year of sillimanite clay (also called kaolinized sillimanite) that contains 40% to 48% Al_2O_3 is produced.
[5]Reported figure.
[6]This category includes kyanite, andalusite, and sillimanite.
[7]Source: Dickson, Ted, 2002, Sillimanite minerals, *in* Industrial minerals annual review supplement: Mining Journal Ltd. CD-ROM, p. 5.